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ABSTRACT

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EXPERIMENTAL INVESTIGATION OF A SPACIAL MODEL OF INFORMATION

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A paper presented at the annual convention of the International Communication Association, Portland, Oregon, April 14-17, 1976.

Abstract

"Experimental Investigation of a Spacial Model of Information"

An experiment tested the hypothesis that cognitive change resulting from information inputs can be represented as linear motion of concepts in multidimensional space. The theoretical background is reviewed and the mathematical derivation of the hypothesis is given. A set of fifteen nations was scaled using Woelfel's Galileo system of multidimensional scaling. Experimental messages were introduced and the posttest inter-concept distances compared with those predicted by theory. The crucial partial correlations were low, a failure to confirm the hypothesis. Secondary analyses suggested that the failure may have resulted from inadequate control of message content and failure to consider the concept of "domain." The theory made better predictions for a subset of the concepts that might be a domain.

Introduction

It is perhaps unnecessary to remark that we would understand a great deal more about human communication if we understood the human mind. That in itself, however, is not sufficient justification for communication theory to embrace cognitive theory. The working assumption of this study is that there is potentially a more specific kinship between the two fields: that formal models of structure can be applied equally well to cognitions and messages, and that constraints on process inherent in those structural models can shape theories of the cognitive effects of communication.

The specific hypothesis tested is taken from Craig (1975).[1] In that paper I distinguished between spacial and network paradigms, developed models of cognition, models of messages and theories of communication effects in terms of each paradigm, and suggested strategies of integrating the two perspectives. I suggested an experiment (Research Design #2) as a potentially "crucial" test of the general hypothesis of spacial structure. That experiment was conducted and the results are reported here.

In the following sections I will (1) discuss the theoretical background of the research and present the derivation of the experimental hypothesis, (2) describe the design, procedures and analysis of the study, (3) present the results and (4) interpret the results, and consider alternative explanations.

Theoretical Background

Spacial Models of Cognition

Several theorists have developed more or less elaborate models of the mind as a multidimensional space in which concepts are defined by their locations. The accumulated evidence strongly suggests the utility of the general spacial model.

Scott (1969), Schroder, Driver and Streufert (1967), Kelly (1963, p. 146), Runkel (1963) and Zajonc (1960) are all cognitive theorists who speak of cognition more or less generally as the projection of a stimulus on a set of psychological dimensions, without, however, elaborating to any great extent the "geometry" of cognitive space.

A far more developed spacial model is that of Osgood and his associates (Osgood, Suci and Tannenbaum, 1957; Osgood, 1974). Osgood introduces the idea of "semantic space" as a model of the "affective meaning system": a coordinate system whose origin is the point of neutral meaning and whose axes are the general factors of a set of bipolar attributes (the semantic differential). Semantic differential research has disclosed that at least some dimensions of semantic space are remarkably stable and invariant across cognitive domains. Osgood, Suci and Tannenbaum (1957) state:

> The same three major factors of evaluation, potency and activity (which were empirically rather than theoretically derived) have reappeared in a wide variety of judgmental situations, particularly where the sampling of concepts has been broad. The relative weights of these factors have been fairly consistent: evaluation accounting for approximately double the amount of variance due to either potency or activity, these two in turn being approximately double the weight of any subsequent factors. (p. 325)

This central finding has held up quite well in subsequent studies in many cultures. Seventeen years after publication of The Measurement of Meaning, Osgood (1974) is able to assert that the accumulated research "is rather convincing evidence for the universality of the affective meaning system" (pp. 33-34).

The semantic space research may be taken as evidence for the existence of stable, spacial cognitive structures. Osgood's methods may be attacked, however, on the ground that they beg the question of whether cognitive space is best thought of as an attribute space. Negative evidence cannot be found by a method which involves measuring meaning on interval attribute scales and factoring those scales; the results will necessarily appear as dimensions.

A broader spacial model of cognition is found in the psychometric literature on multidimensional scaling (Torgerson, 1958; Shepard et al., 1972). Here algorithms have been developed to convert matrices of psychological "distance" or "similarity" among concepts into configurations of points within spacial coordinate systems. The recent "nonmetric" scaling techniques are usually designed to produce a space of minimum dimensionality and maximum interpretability. A review of a sample of the nonmetric scaling literature both tends to further evidence the validity of the general spacial model of cognition and to demonstrate the limitations of Osgood's version of the model.

Many multidimensional scaling (MDS) studies have found interpretable spacial configurations but many of those studies also suggest that not all interpretable multidimensional spacial representations of cognitive structures also have interpretable dimensional structures. Spacial structures may appear as interpretable clusters, circumplexes or other non-dimensional forms. The set of possible forms has been somewhat systematized by Degerman (1972). Rapport and Fillenbaum (1972) demonstrated that color terms in American English scale as a two dimensional circumplex corresponding quite closely to the theoretical color circle, and that "Have" words in American English (return, steal, take, etc.) scale as a set of clusters in space.

When MDS studies have found interpretable dimensions, the dimensions are sometimes similar to the Evaluation, Potency and Activity dimensions of the semantic space and sometimes not. The study of Nations reported by

Wish, Deutsch and Biener (1972) found the evaluation-like dimension of Political Alignment and the potency-like dimension of Economic Development, but also found dimensions of Geography-Population and Culture-Race which have no correspondence with semantic space findings. Rosenberg and Sedlak (1972) found, for personality terms, clear dimensions of good-bad and dominance-submission. Burton (1972) found that occupation names fall long dimensions of Dependency, Prestige and Skill, D'Andrade, et al. (1972) found that disease terms scale by seriousness and contagion.

These studies all give evidence both of the validity of the general spacial model of cognition and the utility of MDS as a way of operationalizing the spacial model. Perhaps more compelling evidence, however, comes from those studies which have related spacial representations to human behavior assumed to depend upon the cognitive similarity of objects. That such relations hold has been demonstrated for the substitutability of consumer products (Stefflre, 1972) and of political candidates (Mauser, 1972): products or candidates found by MDS to be closer together are more likely to be substituted for one another (switched among) in the market or the electoral arena. Jones and Young (1972) found that frequency of social communication could be predicted from distances among people in a spacial representation of a social structure.

In sum, both semantic space and nonmetric MDS research tends to confirm the utility of a spacial model of cognition, in that those studies have shown that the spacial representation is stable, valid on its face, and reliably related to other human behavior.

The most general version of the spacial model has been proposed by Woelfel (e.g., 1974a, 1974b, 1975) and his associates (e.g., Woelfel and Saltiel, 1974; Danes and Woelfel, 1975; Taylor, Barnett and Serota, 1975).

Woelfel frees the spacial model from its attachment to dimensional interpretation and introduces both the novel idea of cognitive change as motion of concepts of multidimensional space and the instrumentation and software to operationalize that idea.

Woelfel postulates that cognition is a process of relating objects of thought to each other. Objects are distinguished by virtue of their attributes. Woelfel's model, however, does not give a central place to attributes as such. Rather, the aggregation of all respects in which two objects of thought differ is taken to underlie an overall dissimilarity or psychological distance between the two objects. Thus distance rather than attribute is the generating concept of the model. There is no assumption of an attribute space spanned by fundamental factors. The dimensions of cognitive space need not in themselves have any psychological significance; nor need the origin of the space mean anything (or nothing!). The cognitive space may exhibit interpretable patterns: dimensions, clusters, or other forms. Or the configuration of concepts may not be at all interpretable. In any case, the configuration "is" just what it "is"; its validity does not depend on its interpretability.

What is of kep import to Woelfel is not the interpretability of cognitive space but its dynamics. Change in the meaning of an object can be represented as movement of the object relative to other objects. The crucial test of Woelfel's model is whether "laws of motion" can be found which parsimoniously account for the changes over time in cognitive space. If such laws cannot be found, or if more parsimonious laws can be found in another paradigm, then the model fails.

Because the relationships it displays can be assumed, even in principle, to be merely ordinal, nonmetric MDS may be considered unsuitable for the investigation of motion in cognitive space. Thus their interest in the study of change has motivated the renewed interest of Woelfel and his associates in the "classical" or "metric" approach, which makes stronger assumptions about measurement. This revived interest has led to the development of the Galileo system--a set of measurement and design techniques and a package of computer programs--which adapts classical MDS to Woelfel's interest in the study of "cultural processes." The Galileo system has been described in detail by Serota (1974), but a succinct overview of the technique is provided by Taylor, Barnett and Serota (1975):

> The subjects are given a complete (n(n-1)/2) list of pair comparisons for the set of concepts being scaled. They are asked to make ratio judgments of the dissimilarity between concepts using the form.
>
> If x and y are u units apart, how far apart are concept a and concept b?
>
> Such an item wording requests a distance judgment from a respondent (". . . how far apart are a and b?"). However, it requests that this judgment be made as a proportion of a standard distance provided by the researcher ("if x and y are u units apart . . ."). This format allows the respondent to report any positive value; the scale is thus unbounded at the high end, continuous, and grounded with a true zero (identity - two concepts are perceived to be the same).
>
> Since the data for an individual case is highly unreliable (reliability being inversely proportional to the difficulty of the judgment task), and since our goal here is a measure of social or cultural conceptions (Serota et al., 1975), we may use aggregation techniques to improve our measurements. By applying the Central Limits Theorem and Law of Large Numbers we find that the arithmatic average of all responses for any cell in the matrix will converge on the true mean for the population as the sample grows large . . . ."*
>
> The mean distance matrix is further transformed to a scalar-products matrix which has been double-centered (Torgerson, 1958) to establish the origin at the centroid of the distribution.

*Studies by Barnett (1972) and by Danes and Woelfel (1975) have achieved adequate levels of reliability with samples of well under one hundred people.

> This matrix is subsequently factored (using a direct iterative, unstandardized procedure) to achieve a coordinate matrix whose columns are orthogonal axes and whose rows are the projections of the concept location on each of the axes . . . . This space has the property of representing the average distance judgments for all possible pairs simultaneously. Additionally, the multidimensional space is constructed from the unstandardized distance vectors between all possible pairs, and all variance in the sample population is thus accounted for by the n-dimensional space.
>
> Finally, this procedure is repeated at each point in time and the spaces are rotated about the centroid to a least-squares best fit to provide approximations of the concept motions over time. From these resultant cross-time coordinate matrices we can fit curves (trajectories) of motion which describe the relational changes from the set. (pp. 4-5)

A more recent addition to the system is an alternative rotation procedure which takes account of theoretical assumptions about which concepts have and have not "moved" during the interval between observations (Woelfel et al., 1975).

Woelfel's model has some shortcomings, the most severe of which arise from the problems of measurement. The model handles measurement very well in principle, but in practice it is just measurement which most seriously limits the model's applicability. The model requires ratio level measurements of psychological distance which, quite simply, cannot be reliably provided by individual human subjects, at least under procedures so far devised. Thus the model, which one would like to describe individual as well as aggregate phenomena, can be tested only on aggregate data.

One could also attack Woelfel's model by citing cognitive structures which it seems unable to describe--my knowledge of how to tie my shoes, for example. But this sort of criticism ignores the large range of phenomena which the model does seem to describe, and avoids rather than attacks the central issues raised by the model, which are both empirical and interesting. No claim of universal synthesis can be made for the model. The literature of cognitive theory is a cornucopia of spaces, networks, schemata, groups, implicational structures, psychologics, algorithms and other paradigms (cf. Zajonc, 1968; Deese, 1969; Weick, 1968). To attempt to subsume all of those models under one model at the present stage would be folly. It would be better, as in the present study, to tackle the issues raised by a specific, well-formulated model, attempting thereby to determine the range of phenomena to which it applies.

The literature strongly supports the inference that spacial models can be meaningful and useful representations of cognitive structures. This is not to say that all cognitive structures can be represented spacially, but is to say that a broad range of structures can be so represented. The question now becomes whether the extensions of the model implied by Woelfel's broad statement of it are equally valid.

Extensions of the Spacial Model: Models of Messages and Theories of Communication Effects

A model of messages is a model of "the formal characteristics of content analytic constructs." (Krippendorf, 1969: 71) A model of messages flowing from the spacial model of cognition holds that a message is an implicit matrix of inter-concept distances, which can be scaled or plotted in the same way as can the cognitive space which it reflects. Such a model might be seen as just an extension of the accepted notion that a message can be scaled, for example, on an attitude continuum. Instead of an implicit attitude we assume an implicit distince matrix. This idea is not entirely new. It might be said to underlie Osgood's (1959) method of "contingency analysis" as well as more recent computational content analysis techniques that permit multidimensional scaling of message content (Smith, 1974).

Once we have constructed a spacial model of messages we can ask how inputs of messages so conceived would affect cognitive structures. This leads directly to a spacial theory of communication effects. At the most primitive level such a theory might assert only that the motion brought about by information would be "meaningful" or "interpretable" in much the same sense as static multidimensional scales tend to be interpretable.

Several studies of Woelfel's model have been claimed to demonstrate meaningful motion. Gilham (1972); Barnett, Serota and Taylor (1974); Taylor, Barnett and Serota (1975); and Woelfel et al. (1975) all report studies in which obtained changes in the locations of concepts generally were successfully interpreted in light of known information inputs. These studies, however, share some important shortcomings. First, despite the purported precision of the model, the interpretative analysis in all cases was qualitative and in two of the studies was entirely post hoc, while in the other two studies it was based on qualitative predictions. Second, in every case the analysis focused on certain changes and ignored others. There seems to have been no attempt made to systematically explain all observed changes, to seek out evidence contrary to theory, or even to account for apparent anomalies.

Thus the evidence for the meaningfulness of motion in cognitive space, while suggestive, is far from conclusive. The research so far has not been very rigorous; and in fact the accumulated evidence largely consists of post hoc interpretations of selected features of the observed changes in spacial locations of concepts. The theoretical work in this area has become quite developed. Needed has been research that will tie together the spacial models of cognition, messages and communication effects in testing precise, a priori hypotheses derived from explicit assumptions.

The research reported in this paper was designed to meet those needs.

A Theory of Linear Motion: Overview

The first step in rigorously testing the idea of meaningful motion is to construct a more specific theory which is falsifiable. One point concerning spacial theories of communication effects should be made clear: the test of any particular theory is not equivalent to a test of the general spacial model. Many spacial theories are possible—some more complicated than others. The theory to be presented here, for example, assumes linear motion in a stable, Euclidian space. Complications such as nonlinear motion and warpage of space could be introduced later if the simpler theory fails to explain data. The general strategy should be to test simpler theories first, and to complicate theories only when forced to by data. It should be recognized, however, that there is a point at which the repeated failure of ever-more-complex theories to account for the observed phenomena would force us to conclude that the general spacial paradigm is unfruitful. So while no study can provide a "crucial" test of the general spacial model (or even, for that matter, of the specific theory under investigation), a study such as the present one can contribute to the ultimate evaluation of the general spacial model.

Suppose that cognitive change resulting from information inputs can be represented as linear motion in multidimensional space. This implies that the change in a concept results in precisely predictable changes in the psychological distances between that concept and all other concepts in cognitive space. The principle can be seen by imagining a number of objects arrayed on a table. Moving one of the objects toward or away from a second object changes the moved object's distances from all other objects in a precisely determined fashion. As applied to human cognition this may seem like a wild hypothesis, but it follows rigorously from a set of assumptions which are not in themselves implausible: a conceptual structure in cognitive space, and a message that is "about" the distances of a concept from some other concept.

In order for our theory to permit numerical predictions we must admit several further assumptions, the most important of which are those that connect the spacial model of messages to the concept of cognitive motion: a theory of communication effects.

For this study the theory chosen was Woelfel's Linear Force Aggregation Theory. Saltiel and Woelfel (1975) explicate the theory and summarize the supporting evidence. One must concede that the evidence for the theory is not terribly strong, and that a look at behavioral research done from other theoretical perspectives--for example, studies of the relation of message discrepancy to attitude change, or of information integration in impression formation--would provide a wealth of evidence suggesting that more complex theories than Woelfel's are required. Since our focus here, however, is not on the exact shape of information processing curves but is rather on testing of the fundamental idea of cognitive motion, the simplicity of the Linear Force Aggregation Theory is attractive. Furthermore, because the theory posits that attitudes are "made out of" accumulated messages, the theory provides a direct link, a linear relationship, between messages and cognitive structures.

The Theory of Linear Motion makes several assumptions beyond those of Linear Force Aggregation Theory. Those assumptions are apparent in the derivation which follows.

A Theory of Linear Motion: Scope Conditions

The theory predicts the time t' distances among a set of concepts (s'_{ij}) given the following:

(i) The following quantities are known: the set of distances between each pair of concepts i and j at time t (s_{ij}), the projection of each concept on each dimension of cognitive space at t (f_{ik}), the inertial mass of each concept (n_i), the number of messages received in the interval $t - t'$ (p), and the set of assertions contained in messages received during the interval $t - t'$ ($\tilde{s}_{ij}$).

(ii) The interval $t - t'$ is sufficient for equilibrium to be established in the cognitive space following receipt of messages.

(iii) No change occurs during the interval $t - t'$ except that induced by known messages.

Derivation of the General Structural Equation

Woelfel's Linear Force Aggregation Theory states that a belief is equal to the mean value of all messages received. Translated into terms of the spacial model,

(1)

$$s_{ij} = \frac{\sum_{k=1}^{n} s_{ijk}}{n},$$

Where: $\bar{s}_{ij}$ = the psychological distance between concepts i and j,

s_{ijk} = the distance proposed by message k,

n = the total number of messages which have located i and j—the 'inertial mass' of s_{ij}.

A direct implication is that the effect of "new" messages on an already established belief is equivalent to a change in a mean given additional values.

(2)

$$s'_{ij} = \frac{ns_{ij} + p\tilde{s}_{ij}}{n + p} = s_{ij} + \frac{p}{n + p} \cdot (\tilde{s}_{ij} - s_{ij})$$

Where: s'_{ij} = the new belief

p = the number of new messages

$\bar{s}_{ij}$ = the mean distance proposed by the new messages

In view of the conclusions of Woelfel and Saltiel (forthcoming), we ought to regard s'_{ij} as an <u>equilibrium value</u> that will be approached over time as the messages are processed. In short, we are dealing here with what strictly might be called "comparative statics" rather than dynamics.

Assume that n, the total number of messages which have located i and j, can be expressed as a sum of two quantities,

(3) $$n = n_i + n_j ,$$

where n_i and n_j are the number of messages which have located i and j, respectively. This assumption allows us to partition the expression on the right in equation (2) so as to reflect the relationship between inertial mass and message effects.

(4) $$s'_{ij} = s_{ij} + \left[\frac{n_i}{n} \cdot \frac{p}{n + p} \cdot (\bar{s}_{ij} - s_{ij})\right] + \left[\frac{n_j}{n} \cdot \frac{p}{n + p} \cdot (\bar{s}_{ij} - s_{ij})\right] ,$$

where the left bracketed expression is the change brought about in j and the right bracketed expression is the change brought about in i. The change brought about, that is, is inversely proportional to the number of messages which has located a concept. In still other words, the change brought about by new messages is "apportioned" between i and j in inverse proportion to their inertial masses.

Now assume that i and j are located in a multidimensional space, and our problem is to determine the change in location of a "moved" concept i with respect to all other concepts in the space. The first step in doing this is to note that s_{ij} can be expressed in terms of the projections of i and j on a set of orthogonal reference axes of the space.

(5) $$s_{ij} = \sqrt{\sum_{k=1}^{r} (f_{ik} - f_{jk})^2},$$

where f_{ik} and f_{jk} are the projections of i and j, respectively, on axis f, and r is the dimensionality of the space. $\tilde{s}_{ij}$ and s'_{ij} can, of course, be expressed similarly.

The general structural equation for post-message pairwise distances among concepts in the space can now be derived in three steps. First, we need an expression for $\tilde{f}_{ik}$, the projection of concept i on axis f as proposed by new messages. Second, we need an expression for f'_{ik}, the new equilibrium for the projection of i on f brought about by the new messages. Third, we can write the general structural equation.

The expression for $\tilde{f}_{ik}$ assumes that one-half of the change <u>proposed</u> by $\tilde{s}_{ij}$ is directed toward concept i, and that the change proposed is apportioned among the dimensions of the space proportionate to the distance between the projections of i and j on the dimensions.

(6) $$\tilde{f}_{ik} = f_{ik} + \frac{(f_{ik} - f_{jk})^2}{(s_{ij})^2} \cdot \frac{1}{2} \cdot (\tilde{s}_{ij} - s_{ij}) \cdot \frac{f_{ik} - f_{jk}}{|f_{ik} - f_{jk}|}.$$

The last factor in expression (5) is needed to determine the sign of the changes proposed in f_{ik}. The expression for f'_{ik}, the post-message equilibrium value of the projection of concept i on axis f, can now be adapted from the appropriate parts of equation (4).

(7) $$f'_{ik} = f_{ik} + \frac{2n_i}{n} \cdot \frac{p}{n+p} \cdot (\tilde{f}_{ik} - f_{ik})$$

In equation (7), $\frac{n_i}{n}$ is multiplied by 2 to take account of the fact that the derivation of $\tilde{s}_{if}$ has already divided the proposed change, and allocated the change to concepts i and j separately. Note that if either $p=0$ or $\tilde{s}_{ij}=s_{ij}$, then equations (6) and (7) result in $f'_{ik}=f_{ik}$. These equations, that is, can be applied to any concept in the space, regardless of whether any messages have affected that concept.

Substitution into equation (5) now gives the general structural equation.

(8) $$s'_{ij} = \sqrt{\sum_{k=1}^{r} (f'_{ik} - f'_{jk})^2} ,$$

where i and j are <u>any</u> two concepts in the space. Equation (8) is a general structural equation in the sense that it gives the post-message distances between all pairs of concepts, including pairs in which neither, one or both concepts have been affected by messages.

Method

A pretest-manipulation-posttest, within-subjects experimental design was used. Subjects were 64 graduate and undergraduate students in communication classes at a large university.

Fifteen concepts were scaled. The concepts were Nations. The Nations were selected by a procedure that combined random and judgmental features.

Three messages were constructed. Each message argued that a pair of nations was either "very similar" or "very different." The messages were of comparable length and structure.

In the pretest the fifteen nations were scaled. The subjects made direct, ratio judgments of the distances between all 105 pairs of concepts. The subjects then read the messages, which were intended to induce motion in six concepts, leaving nine concepts unmoved. The two sets of concepts (manipulated and not) provided experimental control. Theory predicts that specific changes should have occurred in 69 out of the 105 distances among the fifteen concepts, while the remaining 36 distances should not have changed. The subjects also made estimates of the distances between manipulated concepts "in the message," those estimates to be used as estimates of the content of the messages. The subjects also rated the familiarity of the countries. Those ratings were used to estimate the inertial masses of the concepts.

In the posttest (one week later) the subjects again read the three messages, then again estimated the 105 inter-concept distances, which distances were to be compared with those predicted by theory.

Pretest and posttest distances were aggregated across subjects and the mean distance matrices were subjected to metric multidimensional scaling, the second space rotated to comparability with the first by two procedures described by Woelfel et al. (1975): (1) a "no stable concepts" rotation that assumes no real motion has taken place between measurements (least squares best fit of the coordinate matrices), and (2) a "stable concepts" rotation that assumes "real" motion by the six manipulated concepts but no others. Procedure (2) involves translating the coordinate matrices to the centroid of the "stable" (assumed unmoved) concepts before rotation.

A computer program (TESTLAW) was written to input the coordinate matrices and message content and inertial mass estimates and output inter-concept distances and concept coordinate values as predicted by the theory of linear motion under several sets of auxiliary assumptions discussed below. These predicted values could then be compared with those actually observed.

The fundamental hypothesis test is a correlation coefficient between predicted and observed posttest inter-concept distances among concepts. There are, however, many different bases upon which the correlation can be computed. First, two different rotation procedures were used to make the posttest space comparable to the pretest space. Each procedure (because it involves rotation of imaginary coordinates) yields a unique set of "observed" posttest distances as computed from coordinate values. The actually observed distances are, of course, still a third set. Second, there are theoretical grounds for supposing that the distances between concepts on the first few dimensions of cognitive sapce are more valid than the "raw" distances, since the latter include more error. Thus the correlation may be computed on cumulative subsets of the dimensions of cognitive space. Third, since the effects of information, rather than the mere stability of cognitive space, is at issue, the pretest distances should be controlled in the analysis. This may be done by computing partial correlations.

All of these tests were computed and are reported here. Additional correlations were computed and are not reported here. These involved the use of change scores and the prediction of coordinate values. The patterns of these correlations were deemed sufficiently similar to the reported correlations to warrant their exclusion to save space.

Questionnaires, messages, computer programs and supplementary data analyses are available from the author on request.

Results

Multidimensional Scaling Analysis

The results of the metric MDS analysis are given in Tables 1 and 2 and in Figure 1.

Table 1 is the coordinate matrix for the pretest data. Table 2 is the unrotated coordinate matrix for the posttest data. Fifteen roots were extracted from each distance matrix. This result would be theoretically impossible since _n_ points can always be represented in _n_-1 or fewer dimensions. In each case, however, one dimension accounted for approximately none of the variance in the distance matrix. These coordinates, as Serota points out (1974, p. 64), ". . . are artificial and represent rounding error in the computer algorithm . . . ."

Three of the valid roots extracted from the pretest matrix were negative, while two of the fourteen valid posttest roots were negative. The negative roots accounted for about 6.7 percent of the total pretest inter-concept distances (the total of their eigenvalues was -11,553 as compared to a trace of 161,713 for the matrix). The negative roots accounted for about 2.7 percent of the total posttest inter-concept distances (the total of their eigenvalues was -4397 as compared to a trace of 161,192 for the matrix). Similar shrinkage of the imaginary dimensions has been noted in previous studies (e.g., Taylor, Barnett and Serota, 1975).

Figure 1 is a three-dimensional plot of the results of the stable concepts rotation procedure. The figure shows both pretest and posttest locations. The names of the nations have been labeled and the direction of change indicated by arrows. X, the first dimension, runs from left "front" to right "rear"; Y, the second dimension, is vertical; Z, the third dimension, runs from right "front" to left "rear." The X and Y dimensions are readily interpretable as Economic Development and Political Ideology, respectively. The first dimension runs from U.S. and West Germany at the high end through moderately developed Eruopean and Latin American countries to the least developed African and Asian countries at the low end. The second dimension runs from China and U.S.S.R. at one end through various Asian and European countries to the American nations at the low end--a general, although not entirely consistent trend from most radical to most conservative countries. These two dimensions are similar to the first two dimensions found in the nonmetric MDS analysis of nations by Wish, Deutsch and Biener (1972).

The third dimension is not so readily interpretable (nor was it in the Wish et al. study). Regional clustering, however, is evident on the X-Y plane with each quadrant corresponding roughly to a continental zone.

The overall similarity of the scaling results to those obtained by Wish et al. tends to confirm the validity of the present scale.

The reliability of the scale may be assessed in at least two ways. One is to correlate the mean pretest inter-concept distances with the corresponding posttest distances. The correlation for all distances (N=105) was .87; that for unmanipulated distances (those hypothesized not to change, N=36) was .91; that for all manipulated distances (N=69) was .84;

and that for indirectly changed distances (N=66) was .85. Note that the lower correlation for the indirectly changed distances than that for all distances is consistent with the conclusion that the messages had indirect effects as hypothesized.

A second way of assessing reliability is to examine the stability of the coordinate system by correlating the pretest coordinates with the posttest coordinates for each dimension. This, of course, may be strongly influenced by the rotation procedures employed. For the no stable concepts rotation, the reliabilities for the three largest real dimensions were .99, .98 and .95 for the first, second and third dimensions, respectively; and for the two largest imaginary dimensions, were .60 and .90 for the fourteenth and fifteenth dimensions, respectively. For the stable concept rotation, the reliabilities for the first three dimensions were .99, .93 and .94, and for the last two were .52 and .78. The reliabilities seem adequate under both rotation procedures.

I might note, as an aside, that the fair stability of the imaginary dimensions tends to undermine interpretations of such dimensions as indicating measurement error. Whatever psychological meaning the imaginary dimensions may have, they are a stable phenomenon, not error.

Hypothesis Tests

The mean of the absolute changes of the three directly changed distances was 25.8. The mean of the absolute changes of the sixty-six indirectly changed distances was 12.3. The mean of the absolute changes of the thirty-six no change distances was 10.8. This pattern is consistent with the hypothesis.

A more direct test is given by the correlation of predicted with observed posttest inter-concept distances. As discussed above there were many distinct bases on which such a correlation might be computed. The results are presented in Tables 3 and 4.

In Table 3 are the zero order Pearson correlations between the posttest inter-concept distances (s'_{ij}) and those predicted by the theory, either including concept masses in the computations ($\hat{s}m_{ij}$) or excluding concept masses from the computations ($\hat{s}_{ij}$). All of the correlations (which, of course, were highly interdependent) were statistically highly significant. Most were greater than .8. Several general patterns in these correlations may be noted. First, there was a tendency for the correlations for the "computed" posttest distances to increase in magnitude as less dimensions were included in the computations. This would be expected since the larger (lower) dimensions are more stable. The correlations for the actually observed posttest distances, however, fit an opposite pattern, yielding higher correlations for predictions based on more dimensions. This also would be expected, however, since the predictions based on only a few dimensions are not truly comparable to the actually observed posttest distances, which are, as it were, based on all dimensions. Second, different patterns resulted from the different rotation procedures. The stable concepts rotation displayed a pattern, for all but computations based on only the first dimension, of higher correlations for unmanipulated distances than for manipulated distances. The no stable concepts rotation produced no such pattern. The pattern of correlations for the actually observed posttest distances was more similar to the stable concepts than to the no stable concepts rotation--a fact which may suggest the greater validity of the stable concepts procedure. Finally, there was no clear pattern of differences between correlations involving predictions taking account or not taking account of the concept masses. Thus inertial mass, as measured in the present study, did not clearly contribute to the theory's predictive power.

In Table 4 are the first order partial correlations controlling for the pretest inter-concept distances. These correlations were substantially lower than the zero order correlations, demonstrating that much of the accuracy of prediction displayed in Table 10 was due simply to the stability over time of the aggregate cognitive space, a stability rightly assumed by the theory. Three additional facts about this table are worth noting. First, several of the partials were large enough to be statistically significant (the meaning of this, however, is complicated by the inter-dependence of the correlations). Second, the correlations were lowest when restricted to the 66 indirect changes, although a few (including, however, none of those for the actually observed posttest distances) were still large enough to be significant. Third, negative partials were observed for correlations based on the first dimension only, and those correlations are among the largest in the table in absolute magnitude. The negative correlations are clearly contrary to the theory.

Discussion

Evaluation of Results

The results of this study do not appear to support the hypothesis. The correlation of predicted and observed inter-concept distances showed that the theory predicts very well, but only because it predicts the general stability of the cognitive structure. When the pretest scores are statistically controlled, especially when the three direct changes are also removed from the analysis, the predictive power of the theory becomes quite poor in absolute terms: seldom does it account for as much as five percent of the variance in the dependent variable. Isolated correlations might appear promising, but the overall pattern does not.

Certain results are strongly negative in their implications. Were the theory correct, one would expect better results for the stable concepts rotation than for the no stable concepts rotation, since the former assumes the success of the experiment.

Yet the no stable concepts rotation gave results which were, if anything, slightly more supportive of the hypothesis. Even more disturbing are the negative results on the first dimension. Some of the strongest partial correlations are negative correlations for computations based on the first dimension only. These correlations are contrary to the theory.

A closer examination of the plot of the results (Figure 1) may shed some light. The three experimental messages argued that Singapore and Fiji are close, that Congo and Guyana are distant, and that Portugal and Brazil are close. Consider the actual change of these countries as revealed in Figure 1. While the <u>net</u> change in each case was as predicted, the motion was not, as assumed by the theory, directly along the lines connecting the pairs. The slight net convergence of Singapore and Fiji resulted mostly from changes along dimensions not plotted. The two countries actually diverged on the first and third dimensions (in the latter case bypassing one another) and converged on the second dimension only because of Singapore's greater velocity; Fiji moved in the direction opposite to that predicted. Again, Congo and Guyana's net divergence resulted from movements at large angles to the directions predicted. Regardless of rotation procedure one of the most prominent changes was Congo's movement, contrary to prediction, along the second dimension. The divergence of the two nations on the third dimension was about as expected, but their lock-step motion on the first dimension was quite opposite to that predicted. Finally, Portugal and Brazil's net convergence occurred despite Brazil's movements opposite to predictions on the first and third dimensions and Portugal's opposite movement on the first and second dimensions. Net convergence on the second and third dimensions occurred only because the country moving in the "right" direction tended to overtake the other country.

There are evident in the plot other changes that are not interpretable in terms of the hypothesis. Several unmanipulated nations exhibited apparently substantial movements. One noticeable tendency was for the more extreme countries to move inwards in the general direction of the origin—a pattern suggestive of the phenomenon of regression toward the mean. These changes are not interpretable in terms of facts known to the investigator.

Alternative Explanations

Seven alternative explanations of the results have been considered. Some of the explanations save the theory by indicting the experiment, while others point toward different theories.

Four of the seven alternative explanations are regarded as relatively weak or implausible. First, the experiment may have failed due to weak messages. In fact, none of the three messages produced a quite statistically significant change in the distances to which it referred. This, however, was chalked up to the noisiness of the Galileo system of measurement at the individual level of analysis; all analyses in this study were done with aggregated data. Second, some observed changes might be due to messages from the environment beyond the experiment during the week between observations. This cannot be ruled out because there was no separate control group of subjects, but I paid close attention to the mass media that week and have been unable to draw any connection to what happened in the study. Third, the design may not have allowed enough time following the messages for cognitive equilibrium to be established. If this were true it would still not explain changes directionally opposite to those predicted. Fourth, the motion of concepts during the study might have been partially a function of motion that was already underway prior to the study. This implies a Newtonian notion of cognitive "inertia" which needs to be validated in its own right before it can carry much weight in a case such as the present one. These last two explanations could have been ruled out by a second posttest had one been administered.

The fifth explanation is that the experiment failed because the spacial model is radically wrong. One alternative model would be a cognitive network, a set of concepts partially interconnected by various sorts of cognitive links. I have previously discussed this model in some detail (Craig, 1975). Given a large body of literature with which I have become familiar since writing that paper (e.g., Tulving and Donaldson, 1972), I would now give the network model greater weight and a different treatment. A network model, however, explains the present results only in the rather uninformative sense that an incompletely connected network, viewed in terms of a spacial model, would behave strangely. Some indirect tests of the network hypothesis were tried on the present data. These tests failed and are not reported for reasons of space.

A sixth explanation, and one which I find interesting, is that the experimental messages were noisy; they contained "unintended" information, and so moved the concepts in unintended directions.

Here we confront a serious dilemma which no future experiment of this sort can ignore. A realistic and credible message concerning a particular pair of concepts must, it would seem, make references to many "third" concepts by way of introducing points of comparison or contrast between the experimental concepts. In comparing Fiji and Singapore, for example, we said that both were small, tropical, former British colonies, recently independent, and parliamentary democracies. Perhaps the weakest aspect of this study, in retrospect, was its assumption that the information incorporated in the messages would exert force only along the line directly connecting the pairs of manipulated concepts. In retrospect it would have been just as reasonable, and perhaps more reasonable to assume, for example, that saying that Singapore and Fiji are both parliamentary democracies not only would move Singapore and Fiji toward each other but also would move both Singapore and Fiji toward the concept of "parliamentary democracies." This, then, is the dilemma: on the one hand, we want realistic, credible messages; on the other hand, we can only include a limited number of concepts in the multidimensional scaling analysis. It seems that we must choose either ineffective or invalid manipulations.

The dilemma might be avoided if we had a truly adequate spacial model of message content. More immediately, the dilemma might be avoided by thorough pretesting of the messages in several pilot studies which would incorporate, in overlapping parts, all of the concepts referred to in the messages. The meaning of the message would then not be measured as it was in this study, by a single item referring to the single pair of experimental concepts. Rather the meaning would be measured by a set of items referring to a set of reference concepts common to all of the pretest studies and the main study. And the movement of the manipulated concepts would not be predicted to occur along the lines connecting the pairs; nor would the force of the message be assumed divided equally between the two experimental concepts. Rather, the movement of each concept would be predicted as a linear function of its predicted movements with respect to the whole set of reference concepts. The theoretical prediction of "indirect" changes would then be based on a set of concepts included in the main study but not in any of the pilot studies.

By comparison to this ideal set of procedures the messages used in this study were little better than shots in the dark. Can the apparently chaotic movements apparently induced by the experimental messages be explained by assuming that the messages were noisy? The answer, in general, is trivially "yes." Less trivially and more concretely, certain unpredicted changes do seem directly attributable to certain unintended message contents. The example of Singapore and Fiji is a case in point. Both countries, which were said to be parliamentary democracies having capitalist economies, moved toward the "conservative" end of the second dimension, which seemed to represent political ideology. Another case concerns Congo. Congo's movement toward the "radical" end of the second dimension was one of the most prominent changes in the study. This movement, which was not at all predicted, is not at all surprising in view of the assertions, in the message about Congo and Guyana, that Congo has a socialist economy and a one-party government, and is a self-proclaimed "communist" state. Perhaps we could even explain Brazil's movement toward the African cluster as a consequence of the reference in the message to Brazil as a former colony. Perhaps we could explain Guyana's movement in a general "European" direction as a result of references to it as a parliamentary democracy or as a member of the British Commonwealth of Nations.

These post hoc explanations must be viewed with appropriate skepticism.

They do, however, support the general contention that the noisiness of the experimental messages cannot be ruled out as an alternative explanation which preserved the basic character of the theory of linear motion.

A seventh and final explanation is that the concepts in this study failed to behave lawfully because there were too many of them, or because they, or some of them, were not meaningful. Two factors are involved in this explanation. First is the notion of information processing capacity. People can handle only a limited amount of information in a given period of time. If the environment presents information beyond this limit, then excess information is simply not processed systematically. By rough analogy with experiments on short term memory we might suppose that in an experiment such as ours the maximum number of concepts that would behave lawfully would be about seven (Miller, 1960). The second possible factor is meaningfulness. Perhaps we cannot expect a concept to behave lawfully just because it is included in an MDS instrument; perhaps we must know, in addition, whether the concept means anything to the subjects prior to administration of the instrument. How many subjects in our study had ever heard of Guyana or Fiji? Can we claim to have measured the meaning of these concepts, or must we admit to having merely created an apparent meaning by including them along with the rest of the concepts? And can we expect such pseudo-cognitions, if they exist in the study, to behave lawfully?

These two factors point to the concept of "domain," a set of concepts that behave together as a unit, or are, in Scott's (1969) terms, "functionally equivalent." Under this explanation the laws of motion do not apply to just any set of concepts; the concepts must compose a domain. There may be an upper limit to the size of domains. Spaces including more than that number of concepts would not behave lawfully. If the limit is around seven, then this study, with fifteen concepts, exceeds the limit. Or again, there may be some "critical mass" that a concept must attain before it can function as part of a domain. The theory of linear motion has assumed that mass is important only as resistance to motion: the more mass the more resistance. Now we must wonder whether nearly massless concepts are at all capable of lawful motion.

The data of this study were examined from several standpoints in an effort to test this alternative hypothesis. Particular attention was focused on subsets of about seven concepts that might, for one or another reason, constitute a domain. Predictions of distances involving the seven highest mass concepts, and predictions of the smallest third of the inter-concept distances, were examined and found to be no better than predictions for the whole set of distances. Thus the present study offers no direct support for the contention that concepts can belong to a domain only if they have a certain critical mass or if they are close to each other in cognitive space.

A third subset of distances, however, was found to conform more closely to the theory than did the data as a whole. These were the distances among the six manipulated concepts: fifteen distances, or if the three directly changed distances are excluded, twelve distances. Table 5 displays the partial correlations (controlling pretest distances) of predicted with observed posttest distances for the twelve indirectly changed distances among the six manipulated concepts. These partials are, on the whole, substantially higher in absolute magnitude than the corresponding partials in Table 4. Few of them are statistically significant, but then it must be considered that they have only nine degrees of freedom. Had these partials appeared in Table 3 they would have been touted as strong support for the theory, this despite some anomalies among them, most notably the (now even stronger) negative correlations for the first dimension. Three factors seem to favor the theory. The first is the magnitude of the partials. The second is that the best results are achieved with the stable concepts rotation, which assumes the success of the experiment. The third is that the correlations "peak" around the middle of the range of cumulative dimensions (2 through 6 dimensions), which presumably include the greatest proportion of reliable information.

One must, of course, view <u>post hoc</u> analyses with some skepticism. Still we can ask whether this particular subset of the concepts falls under the alternative explanation. Do they compose a "domain" in a sense that the whole set of concepts does not? One interpretation is that the six manipulated concepts constitute a domain just in consequence of being manipulated, which entails both being mentioned in connection with each other and being infused with information in the form of experimental messages that might create the needed "critical mass." This interpretation is interesting, but it should not be taken too seriously until the finding has been replicated.

Conclusion

As I pointed out earlier, a test of a particular theory is not equivalent to a test of the general spacial model. If this study has not been entirely decisive regarding the theory of linear motion, much less has it been decisive concerning the general spacial model. If the theory of linear motion is false, some other cognitive "law of motion," perhaps more complex, may be found to hold. The working assumption of the study, the utility of general, formal models of information, of course, implies a still wider field of inquiry.

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SCALED COORDINATES OF 15 VARIABLES IN A METRIC MULTIDIMENSIONAL SPACE FOR DATA SET 1

NORMAL SOLUTION

	1	2	3	4	5	6	7	8
CHINA	-54.162	99.985	22.751	-39.284	20.642	-.648	-5.990	-1.850
SINGAPOR	-44.846	37.795	57.840	-7.045	-5.912	-12.073	14.593	-35.908
MEXICO	23.726	-62.264	28.516	-30.129	41.942	8.509	-1.565	-15.503
USA	97.413	-63.000	40.220	-30.015	-36.611	-10.672	12.200	-6.475
PORTUGAL	28.463	1.681	-12.317	29.625	53.932	-.525	-7.327	-8.810
POLAND	42.073	51.210	-52.627	29.211	12.762	-36.446	-11.039	2.233
INDIA	-42.575	23.654	25.737	9.874	-31.837	50.896	-34.234	4.763
FIJI	-55.944	6.899	70.130	44.121	.626	-25.800	12.941	39.030
W GERMAN	85.923	10.053	3.223	19.017	-45.797	-19.910	-28.050	6.028
BRAZIL	25.049	-60.919	3.607	-12.864	44.138	15.022	-20.166	20.606
S AFR RE	-64.637	-43.026	-47.096	-27.037	-17.537	3.343	35.705	29.148
GREECE	31.693	-.446	-19.097	58.776	-1.338	46.569	41.568	-17.072
USSR	66.895	85.727	-42.571	-44.078	-5.179	8.762	17.907	11.726
CONGO	-72.496	-43.977	-55.932	-4.465	-22.043	11.713	-24.598	-13.841
GUYANA	-66.575	-43.371	-30.385	4.292	-7.787	-47.787	-1.224	-20.212

EIGENVALUES (ROOTS) OF EIGENVECTOR MATRIX--

1	2	3	4	5	6	7	8
49874.925	39331.236	23973.248	13870.571	12574.309	11094.830	7063.233	5915.262

NUMBER OF ITERATIONS TO DERIVE THE ROOT--

1	2	3	4	5	6	7	8
12	6	7	17	17	7	13	8

PERCENTAGE OF DISTANCE ACCOUNTED FOR BY INDIVIDUAL VECTOR--

1	2	3	4	5	6	7	8
28.785	22.700	13.836	8.005	7.257	6.403	4.076	3.414

CUMULATIVE PERCENTAGES OF REAL DISTANCE ACCOUNTED FOR--

1	2	3	4	5	6	7	8
28.785	51.485	65.321	73.326	80.583	86.986	91.063	94.477

CUMULATIVE PERCENTAGES OF TOTAL (REAL AND IMAGINARY) DISTANCE ACCOUNTED FOR--

1	2	3	4	5	6	7	8
30.841	55.163	69.987	78.565	86.340	93.201	97.569	101.227

TRACE 161713.803

GALILEO COORDINATES OF 15 VARIABLES IN A METRIC MULTIDIMENSIONAL SPACE FOR DATA SET 1

NORMAL SOLUTION

		9	10	11	12	13	14	15
1	CHINA	-1.730	10.868	-5.873	-.117	1.426	-13.008	48.454
2	SINGAPOR	20.626	-24.863	5.815	-.097	.335	17.292	-10.810
3	MEXICO	-.640	30.670	-11.850	.051	.551	13.939	-29.514
4	USA	-3.719	-.397	4.102	.210	-2.344	-6.714	36.098
5	PORTUGAL	-24.641	-25.629	-18.872	.061	-1.624	-2.342	6.900
6	POLAND	14.276	15.077	11.855	.091	-1.529	26.735	17.062
7	INDIA	-23.822	3.408	10.323	-.092	-1.062	14.428	-6.135
8	FIJI	6.831	8.867	-4.961	-.121	-1.204	-12.091	-18.180
9	W GERMAN	.281	-4.977	-16.137	.186	3.301	1.513	-7.810
10	BRAZIL	17.215	-16.238	21.976	.054	1.600	-6.698	4.701
11	C AFR RE	-7.414	-9.062	-9.802	-.140	.757	24.788	13.473
12	GREECE	5.708	9.607	4.881	.068	1.424	-10.511	12.302
13	USSR	-3.355	-2.648	4.235	.145	-.997	-15.036	-45.712
14	CONGO	31.610	.635	-12.779	-.157	-1.629	-17.970	-1.700
15	GUYANA	-31.208	4.681	17.085	-.144	.992	-14.613	-11.060

EIGENVALUES (ROOTS) OF EIGENVECTOR MATRIX--

9	10	11	12	13	14	15
4236.252	3143.681	2189.805	-.233	-36.170	-3303.244	-8213.903

NUMBER OF ITERATIONS TO DERIVE THE ROOT--

9	10	11	12	13	14	15
11	7	4	4	4	39	10

PERCENTAGE OF DISTANCE ACCOUNTED FOR BY INDIVIDUAL VECTOR--

9	10	11	12	13	14	15
2.445	1.814	1.264	-.000	-.021	-1.906	-4.741

CUMULATIVE PERCENTAGES OF REAL DISTANCE ACCOUNTED FOR--

9	10	11	12	13	14	15
96.922	98.736	100.000	100.000	99.979	98.073	93.332

CUMULATIVE PERCENTAGES OF TOTAL (REAL AND IMAGINARY) DISTANCE ACCOUNTED FOR--

9	10	11	12	13	14	15
103.846	105.790	107.144	107.144	107.122	105.079	100.000

TRACE 161713.803

GALILEO COORDINATES OF 15 VARIABLES IN A METRIC MULTIDIMENSIONAL SPACE FOR DATA SET 2

NORMAL SOLUTION

		1	2	3	4	5	6	7	8
1	CHINA	-29.531	96.831	35.139	11.649	-32.473	-7.249	16.677	-1.710
2	SINGAPOR	-40.133	13.401	80.626	15.832	-19.968	1.197	-9.450	29.006
3	MEXICO	9.459	-71.632	20.227	23.436	-33.786	-26.459	12.660	17.682
4	USA	65.878	-51.452	40.173	-54.727	-7.822	-30.467	-17.969	-3.475
5	PORTUGAL	32.229	-20.587	-18.993	63.567	-4.631	33.148	.814	-23.319
6	POLAND	67.019	44.442	-32.247	-12.377	1.627	16.876	48.219	16.898
7	INDIA	-58.771	27.158	3.855	2.735	45.575	-33.391	-30.827	-25.747
8	FIJI	-61.187	-11.730	51.773	-2.443	32.574	47.507	3.476	6.687
9	W GERMAN	66.652	-11.850	2.316	-36.004	13.641	41.271	-29.084	18.401
10	BRAZIL	15.328	-63.419	-4.215	37.942	.176	-18.308	20.424	-18.213
11	C AFR RE	-56.014	-19.986	-50.740	-16.225	-51.417	28.587	-33.620	-22.319
12	GREECE	40.207	13.427	-26.954	37.811	52.829	-12.863	-17.956	16.529
13	USSR	65.279	75.353	-.173	-13.370	-15.193	-14.633	-8.209	-30.463
14	CONGO	-56.987	10.533	-80.215	-8.028	-6.777	-23.716	-6.032	45.736
15	GUYANA	-59.429	-30.488	-12.571	-49.798	25.645	-1.461	50.877	-22.212

EIGENVALUES (ROOTS) OF EIGENVECTOR MATRIX--

40112.700	32068.920	24646.590	15289.903	12373.260	10237.516	9546.532	7477.049

NUMBER OF ITERATIONS TO DERIVE THE ROOT--

12	9	7	9	11	28	11	8

PERCENTAGE OF DISTANCE ACCOUNTED FOR BY INDIVIDUAL VECTOR--

24.224	19.366	14.884	9.234	7.472	6.182	5.765	4.515

CUMULATIVE PERCENTAGES OF REAL DISTANCE ACCOUNTED FOR--

24.224	43.590	58.475	67.708	75.180	81.363	87.128	91.643

CUMULATIVE PERCENTAGES OF TOTAL (REAL AND IMAGINARY) DISTANCE ACCOUNTED FOR--

24.885	44.780	60.070	69.555	77.231	83.583	89.509	94.144

TRACE 161192.507

GALILEO COORDINATES OF 15 VARIABLES IN A METRIC MULTIDIMENSIONAL SPACE FOR DATA SET, 2

NORMAL SOLUTION

		9	10	11	12	13	14	15
1	CHINA	-1.407	31.637	-2.044	-13.804	.264	8.307	.135
2	SINGAPOR	-2.020	-.542	-1.253	20.100	.037	-9.683	-12.602
3	MEXICO	-28.057	-11.394	14.546	-5.992	-.195	-1.140	22.997
4	USA	2.470	-3.470	-11.270	-4.534	-.140	17.595	-17.657
5	PORTUGAL	3.531	.531	9.975	8.000	-.056	25.658	-4.898
6	POLAND	-12.555	-21.797	11.047	-3.401	.121	-8.961	-20.104
7	INDIA	-5.348	-9.244	29.098	-3.739	.074	-3.603	-8.040
8	FIJI	13.573	-26.750	-13.453	-11.446	-.032	3.392	8.399
9	W GERMAN	9.987	28.365	19.728	-.144	-.032	-7.624	11.182
10	BRAZIL	39.250	12.426	-6.663	-4.915	-.173	-20.518	-7.077
11	C AFR RE	-20.527	-2.393	-10.496	-2.989	-.055	-10.635	-7.961
12	GREECE	-30.617	11.527	-26.771	.069	.037	-3.245	1.800
13	USSR	14.836	-21.509	-9.176	8.525	.206	-4.575	22.769
14	CONGO	29.762	-5.047	-.101	2.842	.029	11.105	3.161
15	GUYANA	-12.878	17.660	-3.167	11.439	-.083	3.925	7.979
EIGENVALUES (ROOTS) OF EIGENVECTOR MATRIX--								
		5453.045	4316.995	2948.225	1119.326	.239	-1999.200	-2390.596
NUMBER OF ITERATIONS TO DERIVE THE ROOT--								
		10	7	10	4	8	6	14
PERCENTAGE OF DISTANCE ACCOUNTED FOR BY INDIVIDUAL VECTOR--								
		3.293	2.607	1.780	.676	.000	-1.207	-1.449
CUMULATIVE PERCENTAGES OF REAL DISTANCE ACCOUNTED FOR--								
		94.936	97.543	99.324	100.000	100.000	98.793	97.344
CUMULATIVE PERCENTAGES OF TOTAL (REAL AND IMAGINARY) DISTANCE ACCOUNTED FOR--								
		97.527	100.205	102.034	102.728	102.728	101.488	100.000

TRACE 161192.507

Table 3. Pearson Correlations* of S'_{ij} with $\hat{S}m_{ij}$ and $\hat{S}_{ij}$, Broken Down by Number of Dimensions Included in Computations, by Method of Obtaining S'_{ij}, and by Subsets of Cases.

Distances Included in the Analysis	Dimensions Included in Computations	Predictor A=$\hat{S}m_{ij}$ B=$\hat{S}_{ij}$	S'_{ij} Comp. From No Stable Concepts Rotation	S'_{ij} Comp. From Stable Concepts Rotation	Actually Observed S'_{ij}
All (N=105)	1-15	A	.836	.804	.866
		B	.858	.815	.885
	1-12	A	.864	.825	.867
		B	.878	.831	.885
	1-9	A	.838	.812	.866
		B	.854	.822	.882
	1-6	A	.888	.838	.841
		B	.883	.838	.858
	1-3	A	.921	.917	.821
		B	.922	.922	.828
	1-2	A	.954	.903	.757
		B	.953	.904	.763
	1	A	.964	.973	.619
		B	.964	.973	.619
Unmanipulated Distances Only (N=36)	1-15	A	.862	.929	.914
		B	.862	.929	.914
	1-12	A	.887	.901	.889
		B	.887	.901	.889
	1-9	A	.845	.912	.881
		B	.845	.912	.881
	1-6	A	.878	.922	.857
		B	.878	.922	.857
	1-3	A	.918	.955	.806
		B	.918	.955	.806
	1-2	A	.933	.945	.814
		B	.933	.945	.814
	1	A	.949	.968	.594
		B	.949	.968	.594

Table 3. (continued)

Distances Included in the Analysis	Dimensions Included in Computations	Predictor $A=\hat{S}a_{ij}$ $B=\hat{S}_{ij}$	S'_{ij} Comp. From No Stable Concepts Rotation	S'_{ij} Comp. From Stable Concepts Rotation	Actually Observed S'_{ij}
All Manipulated Distances (N=69)	1-15	A	.824	.759	.836
		B	.862	.773	.867
	1-12	A	.859	.801	.858
		B	.885	.810	.887
	1-9	A	.843	.780	.864
		B	.870	.796	.890
	1-6	A	.891	.808	.847
		B	.898	.807	.872
	1-3	A	.925	.904	.831
		B	.928	.912	.843
	1-2	A	.964	.880	.736
		B	.963	.881	.746
	1	A	.973	.976	.631
		B	.973	.975	.631
Indirectly Changed Distances (N=66)	1-15	A	.826	.752	.849
		B	.837	.747	.851
	1-12	A	.860	.795	.870
		B	.861	.788	.869
	1-9	A	.836	.770	.874
		B	.844	.768	.873
	1-6	A	.876	.788	.855
		B	.877	.785	.860
	1-3	A	.919	.905	.856
		B	.919	.910	.856
	1-2	A	.963	.876	.765
		B	.960	.876	.762
	1	A	.972	.975	.616
		B	.972	.975	.616

* All correlations in this table are significant, p<.001, one-tailed test.

Table 4. First Order Partial Correlations (Controlling S_{ij}) of S'_{ij} with $\hat{S}m_{ij}$ and $\hat{S}_{ij}$, Broken Down by Number of Dimensions Included in Computations, by Method of Obtaining S'_{ij}, and by Subsets of Cases.

Distances Included in the Analysis	Dimensions Included in Computations	Predictor A=$\hat{S}m_{ij}$ B=$\hat{S}_{ij}$	S'_{ij} Comp. From No Stable Concepts Rotation	S'_{ij} Comp. From Stable Concepts Rotation	Actually Observed S'_{ij}
All (N=105)	1-15	A	*** .346	* .209	*** .336
		B	*** .358	** .230	*** .370
	1-12	A	*** .317	* .212	*** .331
		B	*** .330	* .225	*** .360
	1-9	A	** .294	** .228	*** .315
		B	*** .311	** .237	*** .341
	1-6	A	* .186	.057	*** .334
		B	* .200	.091	*** .356
	1-3	A	.142	** .280	** .275
		B	.137	** .260	** .256
	1-2	A	.017	.078	* .194
		B	.051	.120	* .180
	1	A	-.120	***-.346	.060
		B	-.144	***-.317	.032
All Manipulated Distances (N=69)	1-15	A	*** .444	* .224	*** .385
		B	*** .455	* .244	*** .425
	1-12	A	*** .414	* .239	*** .412
		B	*** .425	* .249	*** .444
	1-9	A	*** .388	* .262	*** .402
		B	*** .405	* .264	*** .430
	1-6	A	* .238	.059	*** .420
		B	* .253	.094	*** .450
	1-3	A	* .207	** .357	*** .373
		B	.196	** .325	** .347
	1-2	A	.006	.072	* .261
		B	.050	.116	* .234
	1	A	-.171	***-.436	.074
		B	*-.204	***-.402	.040

Table 4 (continued)

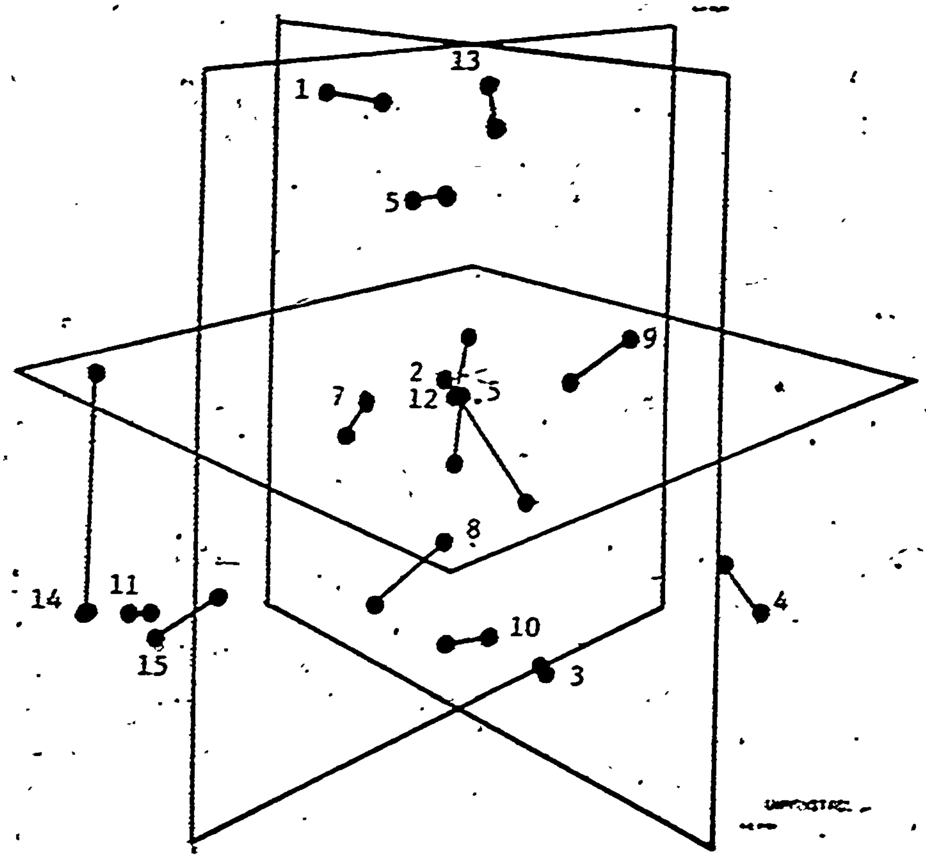
Distances Included in the Analysis	Dimensions Included in Computations	Predictor $A=\hat{S}m_{ij}$ $B=\hat{S}_{ij}$	S'_{ij} Comp. From No Stable Concepts Rotation	S'_{ij} Comp. From Stable Concepts Rotation	Actually Observed S'_{ij}
Indirectly Changed Distances (N=66)	1-15	A	* .242	.062	.150
		B	* .249	.079	.183
	1-12	A	.171	.066	.149
		B	.179	.074	.173
	1-9	A	.204	.094	.137
		B	* .216	.093	.155
	1-6	A	.112	-.021	.165
		B	.126	.024	.187
	1-3	A	.114	* .255	.082
		B	.105	* .227	.052
	1-2	A	-.054	.026	.006
		B	-.004	.080	-.033
	1	A	-.153	***-.424	-.035
		B	-.190	***-.386	-.066

* p<.05, one-tailed test
** p<.01, one-tailed test
*** p<.001, one-tailed test

Table 5. First Order Partial Correlations (Controlling S_{ij}) of S'_{ij} with $\hat{S}m_{ij}$ and $\hat{S}_{ij}$ for Indirectly Changed Distances Among Manipulated Concepts Only.

Dimensions Included in Computations	Predictor $A=\hat{S}m_{ij}$ $B=\hat{S}_{ij}$	S'_{ij} Computed From No Stable Concepts Rotation	S'_{ij} Computed From Stable Concepts Rotation	Actually Observed S'_{ij}
1-15	A	.436	.359	.359
	B	.449	.402	.402
1-12	A	.384	.392	.403
	B	.397	.424	.444
1-9	A	.322	.416	.352
	B	.357	.436	.414
1-6	A	.336	* .532	.511
	B	.321	* .528	* .523
1-3	A	.335	.466	.165
	B	.362	.437	.163
1-2	A	.333	** .775	-.213
	B	.474	** .793	-.138
1	A	-.490	-.512	.004
	B	*-.553	-.484	-.027

* $p<.05$, one-tailed test, d.f. = 9
** $p<.01$, one-tailed test, d.f. = 9



Concepts:

(1) China
(2) Singapore
(3) Mexico
(4) U.S.A.
(5) Portugal
(6) Poland
(7) India
(8) Fiji
(9) West Germany
(10) Brazil
(11) Central African Republic
(12) Greece
(13) U.S.S.R.
(14) Congo
(15) Guyana

Figure 1. Plot of First Three Dimensions, Pretest and Posttest, Stable Concepts Rotation.